With the author's respectful compliments

THE

SMALL-POX EPIDEMIC OF 1870-73

IN RELATION TO VACCINATION

BY

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SMALL-POX EPIDEMIC OF 1870-73 IN RELATION TO VACCINATION.

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THE great epidemic of small-pox which raged in this country in the years 1870-73 was not an unexpected event. Experience has shown that the course of the disease obeys a tolerably definite law of periodicity, and that it recurs in epidemic form at intervals of three, four, or five years. Therefore, since the last previous epidemic had ceased in the beginning of the year 1866, a recurrence was to be looked for about the time at which it actually broke out. Moreover, as the year 1869 drew near its end, a further indication of an impending epidemic was furnished by the returns of the Registrar-General, which showed a gradual increase in the small-pox mortality, at first in London and then in the country generally. This fact was an unmistakable warning that the epidemic, which was at this time fully due —unless the disease was to deviate from the law it was known to have followed for centuries—was now actually about to commence. So clearly was this warning interpreted that, as Dr. Seaton informs us, 'the Lords of Her Majesty's Council (with whom rested the supervision of public vaccination) felt it

incumbent on them to give warning of this to certain metropolitan Boards of Guardians who had been negligent in their administration of the Vaccination Act of 1867, and represent to them the consequences which their neglect would entail on their respective unions.'

The occurrence of an epidemic was thus fully expected. Wholly unexpected, however, was the extreme intensity which the disease assumed all over the country. Ever since the introduction of vaccination there had been so small a mortality from small-pox, and the prevalence of the disease had diminished in such a remarkable manner coincidently with the diffusion of that measure, that in many quarters extravagant hopes had been formed as to the efficacy of vaccination as a protection against small-pox. The great extent, therefore, and the extreme virulence of the epidemic, came as a complete surprise. It seemed difficult at first to see how such an outbreak was compatible with the protective powers which vaccination was supposed to possess. To some writers of authority even this outbreak has proved a stumbling-block, and they have taken up an apologetic position which savours strongly of 'begging the question.' To the anti-vaccinist agitators it has proved a perennial source of specious argument, and they have been eager to declare that it demonstrated clearly the worthlessness of the operation which they condemn. Neither of these positions, however, correctly indicates the true relation of the epidemic to the efficacy of vaccination. On the contrary, it seems to me that a careful examination and analysis of the facts afford the strongest evidence of the protective influence of vaccination against small-pox. That this is so I hope to make clear in this paper, in which I propose to review the chief facts bearing upon the relation of the epidemic of 1870-73 to the question of the efficacy of vaccination.

I am well aware that the subject has already been dealt with by more competent authorities :— by Dr. Seaton, in an elaborate report published in

the annual report for 1874 of the medical officer of the Privy Council and Local Government Board; and more recently by the veteran sanitarian, Dr. Guy, in an interesting and exhaustive paper read before the Statistical Society.* I purpose, however to deal with the subject from a point of view somewhat different from that which was adopted by Dr. Seaton; and Dr. Guy's paper, though covering incidentally the epidemic of 1870-73, was occupied rather with a general review of the prevalence of small-pox in the present century as compared with the two preceding centuries. For these reasons, combined with the fact that the anti-vaccinist agitation has recently broken out with fresh vigour, I hope my observations may not be wholly useless or wholly uninteresting.

In this paper, then, it is proposed to examine (suggestively, rather than exhaustively) the chief facts connected with the small-pox epidemic of 1870-73, in so far as they furnish evidence, positive or negative, in regard to the efficacy of vaccination. The subject will be treated mainly by comparing the conditions and characters of that epidemic with the conditions and characters of similar epidemics in pre-vaccination periods.

In the first place, in order to obtain a correct appreciation of the position occupied by the epidemic in question, it will be necessary briefly to review the prevalence of the disease in previous periods both before and after the introduction of vaccination. This it is possible to do in the case of London alone, as for London alone are there sufficiently reliable and continuous data prior to the introduction of general registration. It is tolerably certain, however, that the epidemic course of the disease was essentially the same in character in the metropolis as in the country at large, and its course in the former may therefore for the purposes of this paper be taken as typical. Accordingly, in the curve figured here I have endeavoured to exhibit the varying prevalence of the disease in London from the beginning of the

* *Journal of the Statistical Society*, September 1882.

seventeenth century to the year 1880. In tracing the curve I have used as the standard of comparison the total deaths at each period. I have made use of this standard, not as the best conceivable, but as the best possible under the circumstances; the standard generally adopted in such cases, viz., the population living at the various periods, being not here available. There are no reliable data by which to estimate accurately the population of the metropolis during the earlier periods to which the curve refers, while the area included by the bills of mortality varied from time to time. Moreover, the deaths registered in the bills were only of such as were buried in the parish churchyards, and were therefore exclusive of a large number of deaths among Dissenters and Papists, as well as some among the adherents of the State Church.* It is obvious, therefore, that it would be impossible with any approach to accuracy to make the population the standard of comparison. The same objections, however, do not apply to the total deaths; and although the latter standard occasionally gives inaccurate results—*e.g.* in the year 1772—yet in all probability it gives on the whole a very near approach to the truth. It has, moreover, the further advantage, as I shall afterwards have occasion to point out, of discounting in great measure the effects of the improving sanitary condition of the people.

For purposes of comparison the diagram also contains a curve for measles traced on the same basis as the curve for small-pox. Measles is a disease which in the behaviour of its contagion bears a striking resemblance to small-pox, and, like it, is also readily recognised by the laity, and therefore likely to have its mortality represented in the bills with a fair amount of accuracy.

On examination of the curve of small-pox it will be readily seen to be divisible into three parts. These represent pretty nearly three periods in the history of small-pox, viz., (1) the period prior to

* Heberden, *Observations on the Increase and Decrease of Different Diseases, &c.* London. 1801.

inoculation, (2) the period of inoculation, and (3) the period of vaccination. The first period may be taken as stretching from 1631 to 1640. Inoculation, indeed, had been introduced in 1721, but it made so little progress up to 1740 that its effect before that date may well be left out of consideration. During this period the curve of small-pox oscillated between the lowest minimum of 3·9 and the highest maximum of 8·3, or about a mean of 6·4. This part of the curve may be taken to represent the natural prevalence of small-pox in a large city (under insanitary conditions) when its course is unmodified either by inoculation or by vaccination.

In 1740 inoculation was revived in the southern counties by the Suttons, and their method of treatment proved so successful that it soon became generally adopted, and during the latter half of the eighteenth century the practice of inoculation became very general, not only in London but throughout the kingdom. Now, although inoculation was in the vast majority of cases beneficial to the individual on whom it was performed—minimising to a very great extent the danger of contracting a loathsome and universal disease at the expense of an exceedingly small amount of risk to life—it was yet of doubtful benefit to the community, inasmuch as the inoculated small-pox was contagious in like manner as the natural disease. Moreover, this danger to the community was all the greater in view of the fact that inoculation was had recourse to chiefly by the classes among whom the natural disease was least liable to spread, at the same time that the other classes of the population were freely exposed to the contagion arising from the small-pox in those who had been inoculated. 'The poor,' writes Heberden, 'who have little care of preserving their lives beyond getting their daily bread, make a very large part of mankind. Their prejudices are strong, and not easily overcome by reason. Hence, while the inoculation of the wealthy keeps up a perpetual source of infection, many others, who either cannot afford or do not choose to adopt the same method, are con-

tinuously exposed to the distemper. And the danger is still increased by the inconsiderate manner in which it has lately been the custom to send into the open air persons in every stage of the disease without any regard to the safety of their neighbours.' Many physicians therefore regarded the practice of inoculation, as it was carried out in the eighteenth century, as extremely likely to raise the general small-pox mortality. As a matter of fact, as a reference to the curve will demonstrate, the small-pox mortality did rise, and it continued high till the practice was discontinued. There are thus good grounds for believing that inoculation did have this effect.*

Towards the close of the century, after the discovery of vaccination, the practice of inoculation fell rapidly into disuse. The agent which, by its perturbing influence during the preceding decades, had caused the small-pox mortality to assume a high level, was then removed. It was, therefore, to be expected, apart altogether from any effect of vaccination, that the curve should now fall; but it was, at the same time, to be expected that the fall should be to, and that the curve should resume its oscillation about, a level similar to that about which the curve had oscillated in the pre-inoculation decades. Looking at the curve it will be seen that a fall did take place almost immediately, but that, instead of assuming the course it was to be expected it should assume, it proceeded still farther rapidly and steadily to decline. It is reasonable, therefore, to assume that some other cause was now at work; that some other perturbing agent had taken the place of inoculation, but that, instead of raising the mortality, the new agent depressed it. This agent, according to the anti-vaccinists, was the improved sanitary condition of the population, but a close examination of the probable effects of that factor will readily enable us to discard it from the position of the only, or even

* It must, however, be pointed out that Dr. Gregory and Dr. Guy have given expression to an opposite opinion, which they support by weighty argument.

the chief, agent. Sanitation has undoubtedly diminished very greatly the total death-rate, and it may have had the effect of diminishing in a somewhat greater degree the small-pox death-rate; but the ratio between the decrease in the total death-rate and the decrease in the small-pox death-rate—which ratio only the curve would show—would be small, and would be very far from the extreme and rapidly-diminishing ratio which the mortality curve really exhibits. If the curve of measles be examined, it will be observed that, instead of decreasing, the percentage mortality has actually increased with improved sanitation. Other zymotic diseases show a similar behaviour. It is impossible, therefore, to suppose that improved sanitation has been the whole cause, or even a prominent cause, in the rapid decline of the small-pox curve, and there seems no escape from the conclusion that vaccination was the principal agent. This conclusion, too, is consistent with the further course of the curve, for just as vaccination had become pretty general, and its influence ought to show so, the curve declined below the pre-inoculation level, and with the diffusion of vaccination the curve still further declined.

In the decade 1871-80 the downward course of the curve was checked, and the mortality of the disease was decidedly increased. This increase was almost wholly due to the enormous rise in the small-pox mortality which took place in the year 1871, when the epidemic of 1870-73 reached its height. This is clearly seen if the year 1871 be omitted in comparing the groups of years. For the nine years 1872-80 the ratio of the small-pox mortality to the total mortality was 1·138 per cent., as against 1·129 for the decennium 1861-70. In the curve on p. 10 (for which I am indebted to Dr. Guy's paper) the pre-eminent position of the maximum of 1871 is distinctly shown. It is based on the same standard of comparison as the previous curve, but shows the annual instead of the decennial variations in the ratio.

It is this great rise in the curve which has afforded

to the anti-vaccinists an argument in their estimation of very great strength. As I have already said, however, this argument will not bear close examination, and this I hope to make clear very speedily.

Ratio of Small-pox Deaths per cent. of Total Deaths.

Before going further, however, it will be well distinctly to lay down the creed—or, if the anti-vaccinists prefer it, the hypothesis—of the vaccinists as regards the efficacy of vaccination. It is held, and

the opinion is based on wide clinical observation, that while vaccination cannot under any circumstances be called an absolute protection against attack of or death by small-pox, it is when efficiently performed an almost absolute protection against attack of and especially death by that disease during the earlier years of life, and when followed by efficient revaccination the protection is renewed for a further period of years, whose limit, if it have any, there is yet no sufficient evidence to decide. According to this hypothesis, therefore, among a population all of whom have been efficiently vaccinated, and, where necessary, efficiently revaccinated, small-pox in epidemic form would be totally unknown, though sporadic cases might occasionally appear, due to introduction of cases from without. On the other hand, among a population of whom a considerable number are unvaccinated, most are inefficiently vaccinated, and very few are revaccinated, that disease would continue to recur in epidemic form in much the same manner as in a totally unvaccinated community. At the same time, however, the epidemics would be rarer and of less extent and severity, by virtue of vaccination, than they would be were vaccination totally neglected. A population of the latter kind described above existed in London in 1870 (and still exists), and therefore on the hypothesis of the vaccinists, the occurrence of an epidemic was not only possible but extremely probable; but, in accordance with the hypothesis, this epidemic was to be expected to be of less severity than it would have been had vaccination never been discovered. How far this expectation was in accord with actual fact it is one of the aims of this paper to point out.

Coming now more particularly to the epidemic itself, let me briefly narrate the history of its commencement and course. For this end I cannot do better than quote the words of Dr. Seaton in the report already referred to. 'The epidemic of small-pox,' he writes, 'which began in England towards the close of 1870 and terminated in the

second quarter of 1873, was part of a general epidemic outbreak of that disease, of world-wide diffusion, marked wherever it occurred by an intensity and malignancy unequalled by any previous epidemic of the disease within living memory. The outbreak seems to have begun in France about a year before it manifested itself in the United Kingdom. In the last quarter of 1869 it was already making considerable progress in Paris. Early in 1870 it prevailed in Orleans, Bordeaux, Lyons, and other large towns, and in the course of the year extended with great mortality over nearly the whole of France, Except, however, in so far as it was directly conveyed by French prisoners to various places in Germany, there was very little extension beyond France till towards quite the close of 1870. The epidemic then manifested itself in London, in one or two of the chief towns of Holland, in Milan, at Geneva, and in some other places, becoming thereafter rapidly diffused over a great part of Europe. During 1871, England and Scotland, Holland, Hamburgh, Prussia, and the whole of North Germany, Italy, and Spain felt the full force of the epidemic ; and the first beginnings of its ravages were experienced in some other countries of Europe as in Ireland and in Denmark. In the course of the year it spread beyond Europe to various parts in Africa (where it raged along the Gold Coast), to the West Indies and to North America. During 1872, while still continuing its course in most countries it had attacked in 1871, it made further extensions over the continent of Europe, invading Austria, Hungary, Russia, and Finland, over Africa, and over North America; it spread also to South America and the South Sea Islands ; and it invaded various parts in the East. In 1873 the greater part of its course in Europe had been run, but there were yet during the earlier part of the year various countries and districts and important capitals, as St. Petersburg and Vienna, still under its influence. By the middle of 1873, however, the pandemic extension of the disease in Europe may be considered to have terminated, and

small-pox generally has since then been quiescent, though there have been some considerable local outbreaks.'

Such, briefly, is the history of the outbreak. I shall now pass to an examination of the circumstances other than vaccination—condition of population, and the like—tending to influence the diffusion of epidemic disease, and compare the character of these circumstances in 1870–73 with their character in pre-vaccination epochs. It will thus be possible to estimate with some degree of accuracy the extent and severity which the epidemic of 1870–73 would have assumed, had it been uninfluenced by vaccination, with the extent and severity which it actually exhibited. The difference, if any, between the estimated and the actual results will afford grounds for answering the question whether and how far vaccination has influenced the epidemic prevalence of small-pox.

The circumstances other than vaccination which may be supposed to affect the introduction and diffusion of epidemics of small-pox may be considered under the following heads :—(1) Density of population ; (2) Facility of intercourse ; (3) State of war or peace, and movement of population ; (4) Proportion of the population insusceptible to attack of the disease by reason of a former attack ; (5) Inoculation ; (6) General hygienic and sanitary conditions of the population. A seventh circumstance might be added—viz., climatic conditions ; but it is certain that but little, if any, difference existed between those conditions in 1870 and in the seventeenth and eighteenth centuries—at any rate, no such difference as to have had any appreciable effect on the course or intensity of epidemic small-pox. There is no call, therefore, to enter into any discussion regarding it. The other heads I shall consider individually.

1. *Density of Population.*—In the period 1870–73 the population of England had enormously increased as compared with its population in the seventeenth and eighteenth centuries. Moreover, this increase

had occurred chiefly in the large cities and large towns, round which, so to speak, the population showed a tendency to condense. The population of the cities and large towns was thus much greater and denser at the time of the epidemic outbreak than it has ever been at any prior period. But it is obvious that the larger and denser the population of a town, the more numerous are the probable sources of the introduction into it of epidemic disease, and the more likely is that epidemic to spread when once it has been introduced. Hence, so far as regards the population, the chances of the outbreak of an epidemic and of its wide diffusion were infinitely greater in the years 1870–73 than in any year before the discovery of vaccination.

2. *Facility of Intercourse.*—It is hardly necessary to point out how immensely greater at the time of the great epidemic of the nineteenth century was the facility of intercourse between different parts of the country. The introduction of good roads, of canals, and above all of railways, rendered transit cheap, easy, and rapid, out of all comparison with what it was in the preceding centuries. This facility of transit multiplied indefinitely the risk of the carriage of infection from town to town, as well as throughout the various parts of the same town. In this respect, therefore, as in respect of the density of population, the latter half of the present century became much more liable to widespread epidemics of small-pox.

3. *Movement of Population.*—The beginning of the epidemic period 1870–73 was a time of war. Crowds of armed men were gathered together from all parts of the two great opposing empires—it may be said from all parts of Europe,—were transferred from place to place, came into collision with one another, and latterly were to a great extent quartered on the civil population of the conquered country. Here then surely were causes sufficient to fan into fierce flame the epidemic seeds that seem always to be present in some quarter or other. To these causes in all probability we owe the wide diffusion

if not also the extreme intensity of the epidemic under discussion.*

Further, the same war and the horrors of the Commune which followed the siege of Paris produced a large immigration of fugitives from France into this country, an immigration involving the danger of the introduction of the epidemic into the latter. Here, again, therefore, was a circumstance especially favourable to the outbreak and spread of a small-pox epidemic, more favourable probably than had ever before occurred in like conditions, not excepting even the unhappy year of 1796.

4. *Proportion of the Population insusceptible to Small-pox by reason of a Previous Attack.*—During the four or five decennia of the present century immediately preceding the epidemic of 1870-73, the mortality from small-pox, as I have already demonstrated, had been very low. The number of persons, therefore, among the population who had been attacked by the disease must have been comparatively small even after making full allowance for the diminution in the fatality of the disease caused by vaccination. In consequence of this, when the epidemic broke out in 1870 there were among the population but few persons who had already passed through an attack of the disease; or, in other words, the proportion of the population insusceptible to the disease by reason of a previous attack was exceedingly small.

On the other hand, during the seventeenth and eighteenth centuries, small-pox constantly presented a very high mortality and every year a large number of persons were attacked by the disease. Hence at the time of any epidemic of the disease there must have been among the population a large proportion of persons who had already been attacked and who were in consequence insusceptible to another attack. The prevalence of

* In an extremely interesting paper read at the 1882 meeting of the National Association for the Promotion of Social Science, Dr. Guy discusses 'The Small-pox Epidemic as affected by States of War and Peace.' (*Journal of the Statistical Society*, Dec. 1882).

small-pox in the pre-vaccination period, indeed, would seem to be comparable to the prevalence of scarlet fever at the present time, and just as now the majority of the population have suffered from scarlet fever in childhood, so then the majority of the population had suffered from small-pox in childhood. This opinion is borne out by the older writers. Hillary* says: 'The small-pox is a distemper so epidemical that there are few but who undergo it at one time or other in their lifetime once.' Again he writes: 'Wherefore the first writers on this disease, seeing them so universal to all mankind, were induced to believe that infants even before their births contracted its contagious matter *a sanguine menstruoso matris*, which afterwards produced the disease by causing a fermentation in the blood at the proper time.' Haygarth, one of the most accurate observers that ever graced the medical profession, declares that 'few or none escape the contagion till they are men and women.'† As illustrative of this fact the latter says that on examining the Cheshire militia he found among 600 men only thirty who had escaped the disease, while a similar proportion was found by him in the Lancashire militia. Further proof is afforded by the ages of those who died of small-pox, and by the proportion which the small-pox deaths bore to the number of registered births. In such detailed accounts of the ravages of small-pox in various places as have been rendered by Haygarth, Percival, Heysham, &c., there is no more striking fact than that the fatal attacks of the disease occurred almost entirely among children of tender age. Moreover, when the number of deaths from small-pox are compared with the number of births the relation is ~~sure~~ to be such as to indicate that the majority of children must have been attacked. Thus Haygarth gives the ratio of small-pox deaths to the number of births, in London 1 to $6\frac{1}{4}$, in Manchester 1 to $6\frac{1}{2}$, in Liverpool 1 to $5\frac{1}{2}$, and in Chester 1 to

* *Rational and Mechanical Essay on the Small-pox.* 1735.

† *Sketch of a Plan to Exterminate the Casual Small-Pox.* London, 1793.

$6\frac{2}{3}$. Now, according to the investigations of Jurin and Scheuchzer the mortality of the natural small-pox was about 1 in 6, and, if this be taken as correct, the number of cases of small-pox must have been very nearly equal to the number of births. If the mortality be taken as 1 in 5, which, for various reasons unnecessary to enter upon here, is probably nearer the truth, there is still a remarkable similarity between the number of cases of small-pox and the number of births.* The similarity becomes still more striking when it is considered that a proportion of the children would probably have died of infantile diseases before having an opportunity of contracting small-pox.

It would be interesting to have some numerical estimate of the proportion of the population rendered insusceptible to the disease in the manner indicated, and I have accordingly attempted to arrive at such estimate. In the case of London, owing to the extensive use of inoculation and to the fact that the population was largely recruited by immigrants from the country, no such estimate can well be made. I have therefore chosen the little Scotch burgh of Kilmarnock, where no such objections apply, and of which there exists a complete register for the thirty-six years, 1728–1764.† The calculation is as follows :—If p represent the annual average population, d the annual average deaths from diseases other than small-pox, and s the annual average number of recoveries from small-pox, who may be supposed to have died of other diseases at the same rate as the general population, and x the annual average proportion of the population protected by a previous attack, then, supposing the

* As illustrative of this point the following paragraph from Haygarth (*Inquiry how to Prevent the Small-pox*) is very instructive. He says :—'At Christleton, a small village two miles distant from Chester, the distemper began in March and continued till October. At the commencement of the epidemic 107 poor children had never been exposed to the variolous infection ; of these 100 had the distemper.'

† 'An Inquiry into the Prevalence of Small-pox in Kilmarnock in the Last Century.' By John C. McVail, M.D. (Read before the Philosophical Society of Glasgow, Feb. 1, 1882.)

proportional death-rates of small-pox and of all diseases to have been the same during previous years as they were during the period 1728-1764,

$$x = xr^n + sr(1 + r + r^2 + r^3 + \quad . \quad . \quad . \quad . \quad + r^n)$$

Where $r = 1 - \frac{d}{p}$ and n = any year counting from any other year during the period in question.

$$\text{Whence } x = s\frac{r}{1-r} = s\frac{p-d}{d}.$$

But $p = 4{,}200$ $d = 107{\cdot}22 - 17{\cdot}27 = 90$ (nearly) and $s = 17{\cdot}2 \times 5$, if the small-pox mortality be taken as 1 in 6.

Whence $x = 3{,}927$; or, if the mortality be taken as 1 in 5, $x = 3{,}142$.

That is to say, that in Kilmarnock during the period taken there were, on the average, about 3,927, or at least 3,142, persons out of a total population of 4,200 who were insusceptible to the disease by having already passed through an attack of the disease.

Whether the estimate thus given for Kilmarnock apply to the large towns of England, whether it be too high or too low, I think there can be no hesitation in concluding from the considerations I have brought forward that the insusceptible portion of the community in the last century formed the larger part. There can be no doubt that, putting aside the question of vaccination, the epidemic of 1870-73 fell upon a much more susceptible population than any epidemic of pre-vaccination years. So far, therefore, as regards this condition alone, there was every reason why the epidemic of 1870-73 should have been not only of great extent, but of much greater extent than any epidemic of the previous centuries.

5. *Inoculation.*—It has been pointed out that inoculation tended to increase the prevalence of small-pox during the latter half of the eighteenth century. This influence, however, was exerted mostly on the endemic prevalence of the disease, for when the disease became epidemic the whole community was more or less exposed to the contagion, and a

few additional foci of contagion furnished by inoculation could have little effect on the general result. Towards the beginning of an epidemic it might indeed have aided the diffusion of the disease, but on the other hand, both the previous inoculations and the inoculations during the epidemic (numerous on account of the dread of the disease) reduced the number of susceptible persons, and so tended to reduce its mortality. On the whole, it may be concluded that this measure had but little effect either one way or another on the total mortality of epidemics.

6. *Sanitary Condition of the Population.*—The sanitary condition of the population, using the term in a wide sense, has been slowly but steadily improving during the last hundred years, and there is no doubt that in 1870-73 that condition was altogether superior to what it had ever been before. The general death-rate had been steadily declining, and it was to be expected that the same causes which affected the general death-rate should also have affected the small-pox death-rate. Perhaps even it was to be expected that the small-pox death-rate should decline in a greater degree than the general death-rate. That the ratio should, however, be much greater is open to very considerable doubt. It may be questioned whether sanitation alone, so far as regards the improvements to which it had yet attained,* can have had any great influence on the prevalence of a disease whose contagion is so intense and so little destructible as that of small-pox. As regards measles, no such great effect has been produced, and it is hardly necessary to point out how almost universal is scarlet-fever at the present time. So also in the case of whooping-cough sanitation has produced but little effect. It may, therefore, I think, be reasonably concluded that while improved sanitation has probably had the effect of diminishing the prevalence of small-pox, the effect produced by

* No account is taken of isolation, because that measure is only now becoming generally adopted by communities for small-pox and the ordinary fevers.

it in this direction must hitherto have been comparatively slight.

Such then are the principal conditions that seem likely to modify in any way the extent of a small-pox epidemic. The first four, I have shown, were such as to render an epidemic of much greater extent in 1870-73 than at any time during the seventeenth or the eighteenth century. The last, and perhaps also the fifth, would have had an opposite tendency, but that tendency, I have pointed out, could not have been very great, and there are certainly no grounds for assuming that it could have neutralised the influence of the others. On the whole, therefore, there is every reason to conclude that, uninfluenced by vaccination, the epidemic of 1870-73 must have been at least equal in extent and severity to any epidemic of pre-vaccination periods. It now remains to compare the epidemic of 1870-73 with the great epidemics which occurred before the discovery of vaccination, with a view to discover how far the former was influenced by the use of vaccination.

In the following tables I have made such a comparison in the case of London and in the case of a few other towns regarding which sufficient data exist.

1. London.

Epidemics and their Years of Greatest Mortality.		Actual Small-pox Deaths.	Small-pox Deaths per cent. of total Deaths.	Small-pox Deaths per million of Population.†
Greatest Epidemic of 17th century	1681	2,982	12·440	4,580 circa.
Greatest Epidemic of 18th century (before inoculation)	1723	3,271	11·203	4,670 ,,
Greatest Epidemics of 18th century (after inoculation had been introduced)	1772	3,992	1·532*	5,320 ,,
	1796	3,548	18·394	4,610 ,,
Epidemic of 1870–73	1871	7,912	9·837	2,430 ,,

* The total deaths this year were greatly in excess of the usual.

† The figures in this column for the 17th and 18th centuries are, of course, only approximate estimates.

2. Provincial Towns.

Towns.	1. Year of Height of Epidemic, 1870-73.	2. Epidemic Period Compared.	3. Actual Small-pox Deaths in Year of Height of Epidemic, 1870-73	4. Actual Small-pox Deaths in Period Compared.	5. Annual Rate per million of Population in Year of Height of Epidemic, 1870-73.	6. Annual Rate per million of Population in Period Compared.
Liverpool	1871	1774	1,919	243	3,900	6,394 circa.
Manchester	1871	1781	267	344	750	9,193 ,,
Carlisle....	1871	1779	20	90	430	9,000 ,,
Leeds	1872	Half of 1781	268	130 (in half-year)	1,000	5,180 ,,
Chester....	1871	1772-77	54	63 (=annual average)	75	3,937 ,,
Warrington	1872	1773	34	211	62	(?)
Kilmarnock	Year ending May 1874	1754	141	95	5,800	22,600 ,,

Note.—The figures in columns 2 and 4 are extracted from the works of Haygarth, Percival, and Heysham, and from the old register of Kilmarnock. Those in column 6 have been deduced from the above, together with population estimated from enumerated populations given in the afore-mentioned works, except in the case of Kilmarnock, whose rate is taken from Dr. McVail's paper (*vide* note, p. 17). The figures in columns 1, 3, and 5 are extracted from, or deduced from figures in, Dr. Seaton's Report and the Reports of the Registrar-General, except in the case of Kilmarnock, where the source is Dr. McVail's paper.

These tables clearly show that the mortality of the year at which the epidemic of 1870-73 was at its

height was very far below the mortality of the great epidemic years in the epoch before vaccination, not only in London, but in those provincial towns regarding which there are reliable data for comparison. Moreover, if the mortality in the year immediately preceding and immediately succeeding the maximum years be taken in conjunction with those maximum years, the epidemic of the nineteenth century will appear of still less intensity than those of the seventeenth and eighteenth centuries. But it has already been shown that, apart from vaccination the surrounding circumstances of the later epidemic were such as on the whole to render that epidemic of greater intensity than, or at any rate of equal intensity to, the earlier epidemics. Exclusive of vaccination, all circumstances combined remain inadequate to explain the difference in the mortality exhibited by the figures. To vaccination, therefore, that difference must be ascribed.

Thus, close examination of the facts and circumstances of the epidemic of 1870-73 leads unhesitatingly to the confirmation of the teaching of clinical experience, that vaccination has effected a diminution in the total deaths from small-pox.

Not only, however, does the epidemic confirm clinical experience in respect of the total deaths from small-pox ; it confirms it also in respect of the greater diminution in the deaths from small-pox among the young. The epidemic, as compared with pre-vaccination outbreaks of the disease, shows a remarkable displacement of mortality. The evidence on this head is very striking, and deserves special attention.

In the epidemics of small-pox which occurred before the introduction of vaccination, the mortality caused by the disease was almost exclusively among the very young This fact, as I have previously mentioned, was sufficiently noted by the older writers, and the extent to which it was true can be shown by illustrative figures. Thus, during the thirty-six years 1798-64, of 622 total deaths from small-pox in Kilmarnock there were only 3 of persons over 20 years of age (one

each at 20, 21, and 26), while there were 492 of children under 6 years. In Chester, in the six years 1772-1777, of 378 total deaths from small-pox 369 were of children under 10, and of these 335 were of children under 5. In Warrington, in the epidemic of 1773, there died of small-pox 211 persons all under the age of 10, of whom 199 were under the age of 5. Finally, in Carlisle, of 241 deaths from small-pox during the nine years 1779-1787, 228 were of children under 5, 8 of children between 5 and 10, and only 5 of persons over 10. From these figures * it may reasonably be concluded that, before the discovery of vaccination, of the total deaths from small-pox, between 80 and 90 per cent. were of children under 5 years of age.

On the other hand, in the epidemic of 1870-73 a comparatively small proportion of the deaths occurred in the very young. In London, *e.g.*, of the 7,982 total deaths from small-pox in the year 1871, only 2,945, or about 37 per cent., were of children under 5; in seventeen of the chief unions of England, of 7,626 total small-pox deaths in the same year, 2,620, or about 34 per cent., occurred in children under 5; and in the eight chief towns of Scotland, of 1,537 small-pox deaths in 1872, 362, or about 24 per cent., were of children under 5†.

It thus appears that in the epidemic of 1870–73 the number of deaths from small-pox among children under 5, as compared with the total number of all ages, was very much less than it was in the eighteenth century. But it has already been shown that the total number of small-pox deaths per million of population was much less in the epidemic of 1870-73 than in the great epidemics of the last century. Hence it follows that the number of deaths among children under 5 per million of the population was enormously less in the later epidemic than in the earlier epidemics. This great saving of infant life in the later epidemic can be explained only on one or other of two hypotheses, viz., either (1) that infants in virtue of their age are now less susceptible

* From the same sources as the figures in columns 2 and 4 of the second table

† From Dr Seaton's paper.

to the disease, or in other words that the nature of the disease has undergone a radical change ; or (2) that vaccination has a protective influence. The first hypothesis may be immediately set aside as untenable, and the second must, therefore, be the true explanation.

In conclusion, although I have endeavoured to render this paper rather suggestive than exhaustive, I think it will be admitted by unprejudiced minds that the facts I have brought forward and the comparisons I have drawn clearly demonstrate the great value of vaccination. They show that when properly examined the epidemic of 1870-73 confirms the teaching of clinical experience. While clinical experience teaches that among the vaccinated small-pox is less intense than among the unvaccinated, the epidemic shows a diminution in the total death-rate to be ascribed only to vaccination ; and while clinical experience teaches that among the very young who are vaccinated small-pox is of much rarer occurrence and infinitely less fatal than among the very young who are unvaccinated, the epidemic shows an enormous decrease in the number of deaths among the very young as compared with the epidemics of pre-vaccination periods. If, then, so great a measure of success has been attained in the imperfect state of the public vaccination in 1870-73, we may surely hope that, with vaccination universally adopted and efficiently performed, small-pox may become unknown as a disease of the very young, and that, with revaccination also universally adopted and efficiently performed, the disease may wholly cease to afflict the country.

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